Attributing Design Decisions in the Evaluation of Game-Based Health Interventions

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Abstract

The use of games as interventions in the domain of health care is often paired with evaluating the effects in randomized clinical trials. The iterative design and development process of games usually also involves an evaluation phase, aimed at identifying improvements for subsequent iterations. Since game design theory and theories from associated fields provide no unified framework for designing successful interventions, interpreting evaluation results and formulating improvements is complicated. This case study explores an approach of monitoring design decisions and corresponding theories throughout the design and development cycle, allowing evaluation results to be attributed to design decisions. Such an approach may allow the game design and development process to iterate the game more efficiently towards use in practice.

Keywords

game design, game development, design cycle, evaluation, validation.

1 Introduction

In the past years, a steep increase in the use of games or game-based tools as health interventions or part of such interventions can be observed – as noted in for example [1] and signified by the launch of a dedicated journal [2]. Results from case studies looking at the effective outcomes of the use of games in health are generally positive and indicate promising results for this field of study; particularly in the domain of exergames. For a case study example see for example [3]; for an extensive literature overview see [4].

Most of the game research in the domain of health care can be characterized as 'evidence based practice'. In such research empirical observations and research designs are employed to establish if an intervention has reached outcome targets. If the empirical outcomes substantiate such a claim, the intervention is characterized as 'successful'. In terms of research design, usually clinical

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randomized controlled trials (RCT) are required to validate proposed interventions before general use in practice [5]. In this context, the increased use of games as health interventions calls for case-by-case statements about the effects of a proposed products, as well as generalized frameworks for setting up and conducting such trials. We find however that most evaluation studies lack the required intrinsic connection to (serious) game design principles and related theories. Our findings were affirmed by various recent sources [6][7].

2 Design and Development Process

The game-based interventions that are the subject of evaluation studies are the result of a design and development process which we will first outline. The process of implementing a game-based health intervention is usually iterative in nature. In order to characterize the distinct types of steps in the implementation process, we can take a closer look at the difference stages in a design cycle as observed in practice – roughly following the human-centered design method for serious games [8]. This method consists of repeatedly conducting four phases: analysis, design, development and evaluation.

The main goal of the first phase (analysis) is to formulate the objectives of the game-based health intervention and identify preconditions for the implementation – such as constraints pertaining to time, budget and the domain and the context of application. In this phase the main activities are (desk) research and formulating the boundaries of the implementation together with stakeholders. Possibly, the first ideas of a promising game concept maybe formulated.

The main goal of the second phase (design) is to specify the design criteria, product specifications and formulate a game concept that meets these requirements. This design may be formalized in a game design document and/or evaluated through (paper) prototyping with a focus group. As such, quick improvements may be made to the design before developing any assets for the final product.

The goal of the third phase (development) is to develop a working version of the game; a non-digital or digital prototype at first or a polished final product in later stages. This phase is the most defined and well-known phase as it heavily draws upon common development methodologies in general IT – such as for example Scrum [9] and/or the spiral model of software development [10].

The goal of the fourth, and final, phase (evaluation) is to evaluate the current game version through various means. Usually, a focus group representing the target audience plays through the game in a context that approaches the real-life context of use in later stages. Furthermore, in earlier stages, expert reviews are used to identify the correct translation of domain knowledge into the game. To complete

the cycle, the results from such an evaluation phase are used to feed into the investigation-stage of the next iteration of the cycle. The design is adjusted, selected improvements are implemented in the development phase and the resulting game version is presented for evaluation. This way, iteratively, the prototype is ideally developed towards an intervention functioning in practice [11].

It is important to note that the design cycle approach outlined above does not operate in a vacuum: the context provided by the domain of application and the body of theory provided by previous research provides opportunities to leverage scientific or operationalized previous findings. According to Hevner [12], this context is characterized by a 'relevance cycle' that takes opportunities from practice and probes proposed solutions in the same domain of application; the 'rigor cycle' imports well known theories and methodologies from the knowledge domain and exports possible new approaches and artifacts for future use. In the field of game-based health interventions, the domain of application is the area of health care in which the intervention is intended while the domain of knowledge is the area of game design and related fields.

3 Problems in Game-Based Health Intervention Evaluation

While the field of serious games design alone has seen an increase in applicable principles and theory, no unified game design theory or framework exists [13]. Furthermore, the models and theory used from related fields such as psychology, persuasive technology and behavior change provide only rough guidelines for game design and are only partially integrated with each other. Especially in the investigation and design phases in the design cycle approach outlined previously, such theories are required to underpin a successful design of a game-based health intervention. Ideally, design decisions about aspects of the game mechanics, game dynamics and game aesthetics should be based on literature or best practices. When moving from a carefully constructed game design to realizing the game in the development phase, we have identified two problems from our experience with such projects. First, as available budgets and development time are limited, corners are often cut when implementing the design leading to a necessarily hampered game as opposed to theory used to design it. Second, carefully considered design decisions in preparing the game concept are lost in the implementation phase as they are not monitored as design decisions into the development phase. The potential of iteratively improving games as health interventions during design and development is limited as opportunities for focused improvement in the next iterative design phase are being missed.

As a result, evaluating the resulting game in an empirical study may provide insights in effectiveness but fails to attribute any conclusions to the corresponding decisions in the design phase [14]. The field of game design and game development for health care thus lacks a general framework that links theory-based design decisions to results from evaluating such interventions [4].

The problem, now, is threefold. First, the translation of decisions made during the design phase may be poorly transmitted into the development phase. This is particularly important ad decisions made under time pressure and budget constraints during development effectively alter the design, which may weaken the conceptual design. Second, the evaluation of the resulting game can only provide findings with regard to that version of the game. However, in an iterative process we are more interested in establishing improvements as design decisions before the next development phase commences. Without a clear link between design decisions and development results such conclusions cannot be coherently drawn. Third, and last, the currently available theory does not present a unified approach to either design or development and as such fails to underpin findings in evaluation of the product with theory used before or during the design phase – which is the overarching cause for the first two problems.

In this paper we aim to outline a design cycle approach to design, development and evaluation of game-based health interventions that connects theory-based design decisions with the findings during evaluation by tracing design decisions through the development phase. Subsequently, we will demonstrate our approach by discussing a small-scale case study in the field of game-based health interventions.

4 Approach Outline

In the previous sections we have identified a number of problems in evaluating game-based health interventions with the goal of validating intended effects and identifying areas of improvement for subsequent iterations of the design cycle. In this section we outline our ideas for a design and development methodology that allows evaluation results to be attributed to the corresponding design decisions and underlying theory. Such an approach may allow findings of the evaluation phase to be attributed to the corresponding design decisions and could, after further development and elaboration, provide a stable framework for improving the design in the most desirable direction during each subsequent iteration of the design cycle.

Before outlining the proposed approach, it is emphasized that it is not our aim to suggest specific game design theories, game design or development practices or

specific evaluation methods. The aim is to establish a method for improving evaluation of both the intervention and underlying theory without promoting or demoting specific theories or applied in constructing the intervention itself. In the case study we have, naturally, adopted a selection of theories and practices which are described in the corresponding sections. However, this selection is not the focus of this approach.

The process of identifying and monitoring requirements has become a standard practice in the field of Software Engineering – for example, see [15]. In the traditional waterfall model [16] requirement engineering is the first phase of development, while agile methods such as Scrum are aimed at continuously identifying and adjusting requirements throughout the project. While such an approach is beneficial to the development of game-based health interventions – and often adopted as such – it does not provide sufficient methods to answer to the problems identified in the field of game design. An emphasis on non-functional requirements and the importance of affective components of gameplay are some of the factors that differentiate game design from software engineering. Also, software engineering is usually based on the premise of optimally supporting a user in performing a certain task, whereas game design aims to establish a meaningful experience for a player. The objectives in game-based health interventions are the indirect result of this experience, rather than the direct result of using the game.

In the initial phase of analysis, the objectives and preconditions of the intervention are to be formulated. In the field of health interventions, many objectives emerge from the application domain and are external to the intervention itself – for example, a training objective may be formalized in terms of an increased capacity of the players to perform a certain task. Such external objectives establish the primary outline for subsequent evaluation. During the analysis phase, however, applicable theories from the field of game design that may be leveraged to change knowledge, skills and behavior of the players must also be identified – for example, the theory of flow [17] may be selected in order to keep players motivated to continue playing long enough to benefit from the intervention. Such game design choices establish a secondary outline for subsequent evaluation. Finally, in the analysis phase other conditions and limitations for development – for example budget and available time – are identified. The result of the analysis phase thus is an informed selection of application domain and knowledge domain objectives and methods that, in combination, may provide the outlines for an effective intervention.

In the second phase of design, the goal is to specify a concept for the game-based health intervention that uses the selected theories to guide the players towards the selected objectives within the available limitations. As our aim is to focus on the approach, we will not elaborate on the complex and creative process of designing a

successful game in this context, without a unified framework for (serious) game design. The key in our approach is, however, to document any design decisions in combination with the objectives and theories they relate to. For example, if the game concept describes an increased difficulty level over time, we document that the theory of flow is the theoretic basis for selecting such an aspect. If the game concept involves gesture-based control by the player, we document that the objective of exercising a certain gesture is the practical basis for selecting such a control scheme. The result of the design phase thus is a formalized game concept that meets the criteria from the analysis phase, annotated with the underlying considerations for designing the game in the chosen way.

In the third phase of development, the goal is to develop a useable version of the game. The process of development is, in practice, largely based on software engineering methodology. Maintaining the design cycle approach, no conceptual or creative adjustments should be made during this phase. In practice, however, progressive insight, effects of under- or overestimating the required effort or costs, etc., may lead to on-the-fly adjustments. For example, a certain feature may be excluded due to lack of sufficient development time. In our design cycle approach, such adjustments must again be noted in conjunction with the underlying considerations. The result thus is a playable version of the game-based intervention with possibly a number of implemented changes to the original concept.

In the fourth phase of evaluation, the goal is to establish to what extent the constructed intervention meets the objectives and requirements from the initial phase. Established practices of co-creation, focus groups, usability testing, talk-a-loud etc., may be used to gather insights into the player experience established by the intervention. We loosely use the term player experience to cover the results identified in both the objectives from the application domain (of health care) and the methods from the knowledge domain (of game design). The key to benefit from evaluation for improvement as well as validation is to interpret the results correctly. In our approach, we have emphasized the need to document objectives and theories from the analysis phase throughout the design and development phases. This approach allows results from the evaluation phase to be interpreted by attributing specific results to specific design decisions. As such, the current version of the intervention can be evaluated with increased focus. Moreover, the design choices and underlying theory are being evaluated in their own respect. While drafting conclusions on the intervention itself, we can attribute such conclusions to the underlying design choices by tracing the results back through development and design into the analysis phase. The result of the evaluation phase thus is a series of conclusions on the effectiveness of the game – in terms of application domain objectives and knowledge domain methods – attributed to corresponding design choices and theories.

In outlining the method in the previous paragraphs, the focus is on the initial iteration of the design cycle, which is usually aimed at identifying areas of improvement to be addressed in a subsequent iteration. The approach of attributing design decisions is then used to reconsider design decisions and, as a consequence, the game concept. In later iterations, evaluation may be increasingly aimed at validating the effectiveness of the intervention. The approach of attributing design decisions may then be used to identify the choices that are responsible for the observed effects.

5 Pilot-Study in Physiotherapy

We have adopted the previously outlined approach of tracking design decisions in conjunction with the underlying theory supporting those decisions in a pilot study, to assess the benefits and complications of linking evaluation results to theory per design decision. The context of this study was the desire to develop an iPad-based game for use with a so-called balance board – a board suspended on a hemisphere used to exercise balance as the board will only remain horizontally oriented through active balancing by the person standing on it. Leveraging the fun-factor of games to motivate clients to carry out their home exercises as part of therapy, we aimed to increase the therapy efficacy while away from the physiotherapy practice. We designed and developed an iPad-game using tilt-control to be used within the balance board while the game scene is presented on a connected Apple TV screen. The game is a 3D maze-navigation game with various sub goals such as opening gates and collecting treasures. The player controls the game by tilting the balance board – and thus the iPad – in the direction of movement and subsequently returning the system to the horizontal position. This moves the main character one step/square in the maze at the time, thus requiring repetition of the exercise to navigate the maze successfully. The level designs for the mazes are constructed such that the appropriate exercises are most likely to occur – for example a balanced mix of left, right, forward and backward movements or particular emphasis on one of the directions. Impressions of the balance board and the game are shown in Fig. 1. The project of designing, developing and evaluating the game is extensively documented in the corresponding graduation report [18].

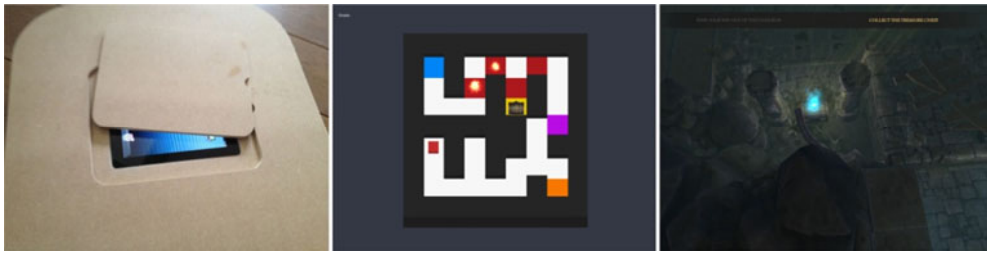

Fig. 1: Impression of the game setup; from left to right: (a) the balance board with an iPad embedded; (b) an early 2D-prototype of the maze navigation game and (c) a screenshot of a further elaborated 3D version of the game.

As the first step in the analysis phase, a selection of applicable theories and models was made to base the design of the game upon – given the aforementioned objective of increasing therapy efficacy. Such a selection was made from both (serious) game design theories as well as domain-specific theory from physiotherapy. For example, common game design frameworks such as the MDA-framework [19], principles such as flow [17] and general game design principles from Schell [13], Rogers [20] and Bartle [21] were used in combination with for example persuasive technology principles from Fogg [22] and Cialdini [23]. In the design phase such models from theory were translated into specific and categorized design criteria for the implementation of the game. In particular, the design criteria were labeled and formulated towards implementation in the development phase.

In this pilot, the proposed game can roughly be divided into three components: a small pre-game component (including introduction, main menu and instructions), a core game component (the gameplay and in-game feedback itself) and a small post-game component (providing generalized feedback towards the number of movements exercised and an indicative judgment of the performance). Drawing from various theories, the design specifications were categorized by this subdivision and labeled with the underlying theories to support the corresponding design decision. A summarized example of this approach is shown in Table 1.

The total of design criteria and product specifications were used as input for the design phase, during which a game design for the maze game was constructed based on the selected theories. To organize the specifications we used both the component-subdivision of pre-game, game and post-game aspects as well as a subdivision into the categories interface, functionality and graphics. In this manner, as the game design was elaborated and formalized in a game design document, the underlying design decisions and corresponding theory were tracked. During the development phase the game was implemented according to the game design, while monitoring design decisions and ticking off implemented specifications.

Table 1: An example of selected theory and design guidelines in the design phase of the game, ordered by the component-subdivision of the game. Since the mentioned theory is shown only as an illustration of the approach, no citations are included with this table.

Component	Theory Label	Summary (paraphrased)
Game	Rogers, S.; accelerometer controls.	"Emphasize accelerometer-control by enlarging small real-world movements to large in-game effects."
Game	Schell, J.; camera perspective.	"Leverage the power of the camera to focus the player on the gameplay."
Game	Schell, J.; puzzle design.	"Provide the answer to the puzzle."
Game	Schell, J.; game design.	"Provide the player with genuine choices."
Pre-game Post-game	Rogers, S.; interface design	"Create an interface that conveys the style and setting of the game."
	Isbister, K. et al.; game usability.	"Create an interface that depicts the game state in a clear fashion."

The specific goal in the evaluation phase of this project was to assess the effective quality of the prototype. The conclusions drawn from the evaluation phase can be used to further improve the game-based intervention towards use in practice in subsequent iterations of the design cycle. In this study, we have conducted an expert review with three physiotherapists to validate the incorporated domain knowledge. Furthermore, we have play tested with a focus group consisting of four physiotherapy clients in the age group of 15-80 in the setting of a physiotherapy practice. For a first iteration, a small focus group may provide rough insights into the areas for improvement. In later iterations of this project we may evaluate for validation of the interventions using a (much) larger test group. The play test was conducted by providing players with a basic introduction to the game followed by an unguided session of playing through the game. The observations during the play test were verified in post-playing interviews with the players.

As expected, during trials with actual clients a number of possible improvements in the prototype turned up. For example, clients reported that the required tilt angle for control was too large for the game to register the actual tilting. Also, players reported problems with interpreting the in-game prompts and the location of the main character. Further comments focused on the lack of challenge in solving the puzzle of the maze and a disconnected feeling towards the game's interface. Using the previously described design criteria sourced in theory, combined with the component subdivision of the game, the test results can be attributed to their corresponding design decision. As an example, this link is shown for a selection of test results in the first three columns of Table 2.

Table 2: Relating test results to design decisions and corresponding underlying theory using the component-subdivision of the game. Since the mentioned theory is shown only as an illustration of the approach, no citations are included with this table.

Component	Test Result	Theory Label	Analysis	Improvement
Game	The minimum tilt angle is too large to effectively move the character.	Rogers, S.; accelerometer controls.	The character cannot be moved by tilting the board because the required tilt setting for detecting a successful tilt is ill-adjusted.	Adjust the angle in accordance with a realistic tilt angle determined from testing.
Game	The location of the main character in the maze is unclear.	Schell, J.; camera perspective.	The shape and color of the main character is too indistinctive w.r.t. other elements of the scene. Also, the camera does not focus on the character, requiring the player to search.	Adjust the shape and color of the main character to stand out more. Adjust camera movement to always focus on the main character.
Game	The puzzle of solving the maze is not challenging enough to be motivating.	Schell, J.; puzzle design.	The entire maze is in view, allowing the player to solve the maze mental-ly before ex-ploring. While theory mandates a full view of the puzzle, the solution is too apparent too soon.	Adjust the camera perspective such that only a portion of the maze is visible at any time.

Component	Test Result	Theory Label	Analysis	Improvement
Game	It is impossible for the player to lose the game.	Schell, J.; game design.	There is no choice for the player not to succeed – let alone stopping playing the game. Game design theory desires [complications]	Introduce damaging elements in the maze and allow the player to 'game over'.
Pre-game Post-game	The interface of the game feels disconnected from the game world.	Rogers, S.; interface design Isbister, K. et al.; game usability.	The interface feels disconnected from the style and setting of the game world, breaking part of the experience. Theory promotes game interfaces in the theme and style of the game.	Develop a game-specific interface in a matching style to emphasize the in-game experience throughout the application.

The conducted expert review validated the translation of the intended exercise objectives in the context of physiotherapy. Since the actual exercise movement is external to the game through the use of the balance board, this is only as expected. Additionally, experts supported the clients' claims regarding the disconnected feel of the user interface. Finally, while experts expected forward/backward movements on the balance board to be as demanding as left/right movements, it turned out that forward/backward movements are more challenging to perform. The results of the expert review did not bring up radically different or additional insights into the design of the game itself.

As Table 2 shows in the last two columns, it is straightforward to reconsider the application of theory and propose improvements for the game. In other words, evaluation results are attributable to design decisions within the frame of reference of corresponding theories. For example, the claims that the puzzle is not challenging enough because its solution is obvious from the start, made us reconsider the decision of showing the entire puzzle. As the theory-link shows, this decision was arrived upon by following the puzzle design guidelines outlined by Schell [13], which suggest providing the solution to the puzzle from the start. However, after finding the members of the focus group unchallenged by this

presentation, we reconsidered the guidelines from the theory underlying this design decision. The difficulty in game design that stems from the inherent divide between designer and user is indicating a different result in this particular case.

In this case study we have adopted an approach of tracking design decisions in conjunction with the underlying theories in order to be able to improve interpretation of the evaluation results. We have found that interpreting evaluation results is more focused and straightforward because the theoretic context is made available after design and development phases. The process of systematically tracking theoretic backgrounds with the design decisions throughout all phases of the design cycle allows the results of the evaluation phase – be it a focus group play test or an expert review – to be attributed to these decisions. By reconsidering the design of the game from a focused theoretic perspective – rather than reconsidering the implementation alone – the design and development process iterates more efficiently towards a successful game-based health intervention ready for use in practice. One drawback of this approach is that a larger part of available resources is invested in monitoring design decisions in all phases of the design cycle.

6 Conclusions

The approach outlined in the previous description of the balancing exercise project describes the first steps to how decisions made during the design phase of the construction of game-based health intervention can be identified and made traceable during the development phase. Such an approach has the benefit of shifting attention away from make-do decisions during development and focusing on the underlying design decisions instead. This reduces development time and as such benefits both developers and practitioners. Furthermore, this approach allows the evaluation phase of the game to not only draw conclusions towards the workings and effectiveness of the individual game mechanics. This benefits both the process of evaluation and the adjustments in the design in the subsequent iteration of the design cycle. Monitoring design specifications in this manner may very well benefit the focus and management of production throughout the development cycle; this perspective is not further explored in this study. We believe that such an approach generally allows for more optimized iteration towards a successful intervention.

Additionally, the tracking of specific design decisions throughout the development cycle sheds light on the way development decisions influence the effectiveness of the design. As we are limited to evaluating products rather than designs, insight in the translation of a theory-based game concept into an operational prototype or finished game is a necessary condition for developing a unified framework for

design, development and evaluation of health games. The outlined approach explores ways of linking together design, development and evaluation into such a unified framework.

The approach outlined in this paper is only a first attempt at establishing a design cycle-based method of improving the effectiveness of evaluation. Future research in this area is required to refine the methodology of such an approach – both in terms of research methodology in design research using the design cycle, as well as in its application to game design and game development and evaluation. The elaboration of this approach may well benefit from software engineering and game production methods existing in practice. Furthermore, an elaborated version of the approach needs an extended evaluation both in sample size and variation in application (sub)domain. The main objective of future research is to establish best practices for the design and development process of health games and bridging the gap between design and evaluation through attributable evaluation results.

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